# A readiness self-assessment model for implementing green lean six sigma initiatives in manufacturing

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## Abstract

Green deployment of Lean Six Sigma (LSS) projects is essential but unknown among scholars and practitioners. Therefore, we aim at identifying top readiness factors of green deployment of LSS projects. A survey questionnaire was distributed to LSS experts and academics around the world. A Principal Component Analysis (PCA) was conducted to identify top readiness factors. The analysis revealed seven new dimensions for critical success factors (CSFs), critical failure factors (CFFs) and barriers, and five new dimensions for motivators. This study serves as an initial call for managers and research scholars to favour the sustainable deployment of LSS projects in manufacturing.

**Keywords:** Lean Six Sigma, environmental sustainability, manufacturing

**Introduction**

Addressing a balanced approach to both positive economic and environmental development performance is a big challenge for manufacturers (Ye et al., 2020). Therefore, the integration of environmental sustainability and energy efficiency into continuous improvement (CI) methodologies such as LSS is becoming a necessity in manufacturing activities (Parmar and Desai, 2020; Farrukh et al., 2020; Erdil et al., 2018; De Freitas et al., 2017; Kaswan, 2019). LSS is usually considered as an outcome-oriented methodology with its positive role for economic sustainability through reducing waste generation in the scenario of green products development (Gaikward and Sunnapwar, 2021; Ali et al., 2020; Farrukh et al., 2020; De Freitas et al., 2017; Sagnak and Kazancoglu, 2016). This enlightened the green LSS integration with the motivation of green outcomes with less product waste (Ali et al., 2020; Farrukh et al., 2020; Belhadi et al., 2020; Mishra, 2019; Ruben at al., 2018; Sreedharan et al., 2018; and De Freitas et al., 2017).

Nevertheless, the green deployment of LSS projects with more resource efficiency and less environmental impact in their life cycle has been neglected by scholars and practitioners due to a profound focus on economic and quality–centred objectives of LSS

(Gaikward and Sunnapwar, 2021; Farrukh et al., 2020; Parmar and Desai, 2020; Erdil, et al., 2018; and De Freitas and Costa, 2017). This gap highlights a need for manufacturing organisations that embark on LSS to be ready to shift from their currently used narrow, outcome–-oriented approach to the use of an energy- efficient and outcome-oriented LSS project deployment. This encompasses identifying top readiness factors of green and energy energy-efficient deployment of LSS projects through conducting a global empirical study. Therefore, this paper aims at identifying critical success factors (CSFs), critical failure factors (CFFs), motivators and barriers (Sreedharan, et al., 2019). As part of this readiness assessment, the paper addresses the research question (RQ) "what is the new set of top CSFs, CFFs, motivators and barriers of green deployment of LSS projects in a manufacturing setting?"

**Conceptualisation and development of the theoretical constructs**

The theoretical underpinning of the present research focuses on sustainable manufacturing and LSS as it aimed at developing an integrated conceptual model covering these theories to address the RQ. The integration of environmental management systems with LSS has been suggested to develop measurement system analyses and gage control essential for effective green manufacturing (GM) (Sagnak and Kazancoglu, 2016).

LSS is defined as a business improvement methodology that aims to maximise shareholder value by improving quality, speed, customer satisfaction and cost-efficiency (Laureani and Antony, 2018). In addition to strategic benefits, LSS aims to clarify the manufacturing process of identifying opportunities for problem-solving, waste reduction, environmental sustainability, learning environment, facilitating innovative minds, as well as reduce defects variability and improve the quality of manufacturing processes (Costa et al., 2021; Ali et al., 2020; Cherrafi et al., 2017; and De Freitas et al., 2017).

The transformation from a customer-centric to a more stakeholder-centric LSS seems to be a challenging and puzzling reality to maximise benefits, including the green deployment of LSS, which requires readiness assessment (Aboelmaged, 2018). The strategic adaptation of a sustainability vision through a holistic evaluation of real data about the positive and negative impact of LSS projects on the environmental dimension of sustainability has been highlighted as a potential future research direction (Belhadi et al., 2020; and De Freitas et al., 2017).

Green LSS enables LSS projects to be conducted based on healthy and sustainable business practices through environmental performance measurement (Ruben et al., 2017). Respectively, a paradigm shift into green and resource-efficient LSS deployment in manufacturing settings seem to be apparent, but un-tapped. Previously, various studies (Sreedharan et al., 2019) have reviewed LSS readiness in different industrial contexts including green integration through CSFs, CFFs, motivators and barriers (table 1). Therefore, it is required to investigate the readiness of manufacturers that embarked on LSS through four different constructs (CSFs, CFFs, motivators, barriers) in order to identify whether new sets of dynamic capabilities are required for the green deployment of LSS projects (Sreedharan et al., 2019).

The CSFs adopted in this study include personal and corporate competencies such as knowledge, skills and charisma. CFFs are key elements that can make things go wrong in the implementation of LSS. If any LSS project does not meet the potential benefits and bottom line sufficiently due to the absence or insufficiency of any CSF, it will be classified as a failure. The implementation of energy-efficient and green deployment of

LSS is a new topic to LSS practitioners and scholars (Shokri et al, 2021). Therefore, as part of a readiness assessment, critical motivators and barriers for transforming the currently used narrow, outcome-oriented approach of LSS to the hybrid model of energy-efficient and outcome-oriented LSS project deployment need to be identified. Motivators are prerequisites that provide stimulus to organisations to apply a new approach (Kaswan, 2019). Barriers are restrictions or insufficiency of motivators that imped organisational change towards new approaches such as green LSS integration. It should be considered as a precautionary measure to reduce future failure of more efficient and effective green LSS integration (Shokri et al., 2021; and Sreedharan et al., 2018).

*Table 1- Readiness factors for LSS and green LSS integration*

| Readiness construct | Relevant factors/variables | References |
|---|---|---|
| CSFs | -Transactional leadership, Project management, Financial accountability | Laureani and Antony, 2018 |
| | Top management commitment, Rewarding, Training, Capital investment | Parmar and Desai, 2020 |
| | Organisational change, resources | Ng and Hempel (2017) |
| | -Engaging managers and employees, core values, strategic project selection, project manager selection, organisational infra-structure, customer focus, project tracking, supply chain management | Sreedharan et al., 2019; |
| | -Structured multi-attitude decision making approach, integrated green LSS framework, committed cross-functional project team | Ruben et al., 2018; and Cherrafi et al., 2017 |
| CFFs | -Lack of top management commitment, insufficient required training, poor project selection, insufficient resources, lack of knowledge, unavailability of data, and lack of strategic alignment in project selection, lack of resources | Swarnakar et al., 2020; De Freitas and Costa, 2017 |
| | -Difficulty in cultural change | Ruben et al., 2018 |
| | Project deficiency, inadequate quality maturity deficiency | Hudnurkar et al. (2019) |
| | -Lack of environmental knowledge, lack of strategic alignment between green and LSS, complications in implementation | Swarnakar et al., 2020 |
| | -Unwillingness by managers, resistance to change | Habidin and Yusof, 2013 |
| Motivators | -Long term energy strategy, need for energy efficiency and competitiveness, legislative demand, international standards, enthusiasm, green innovation, stakeholder demand, satisfying customer demand, knowledge and publicity | Garza-Reyes et al., 2018; Subramanian and Abdulrahman, 2017 |
| | -Cost reduction, financial incentives, profit margin protection and changing competitive positions | Subramanian and Abdulrahman, 2017 |
| | -Collaborative empirical research-based framework | Sreedharan et al., (2018) |
| Barriers | -Inadequate understanding and knowledge, insufficient organisational culture | Garza Reyes et al., (2018) |
| | -Inadequate top management and employee's commitment, resistance to change, fear factor, insufficient resources and knowledge, wide-spread organisational cultural change, lack of | Farrukh et al., 2020; Sreedharan et al., 2018; De Freitas et al., 2017 |

| | | |
|---|---|---|
| | environmental policy, capital investment, narrow target orientation, poor organisational infrastructure, lack of information and data clarity and availability, insufficient environmental drive and competence, weak legislation, competition and uncertainty<br>-Trade-off between economic and environmental performance indicators | De Freitas et al., 2017 |

Despite longitudinal studies about CSFs, CFFs, motivators of and barriers to LSS and green LSS integration with green outcomes (table 1), studies identifying these readiness factors for green deployment of LSS projects seem to be scarce. Therefore, we intend to investigate what are CSFs (RQ1), CFFs (RQ2), motivators to (RQ3) and barriers of (RQ4) green deployment of LSS projects for a manufacturing setting as part of our empirical study. The conducted extensive and critical literature review contributed to the development of a conceptual model of the readiness assessment for the green deployment of LSS projects within the manufacturing context (figure 1).

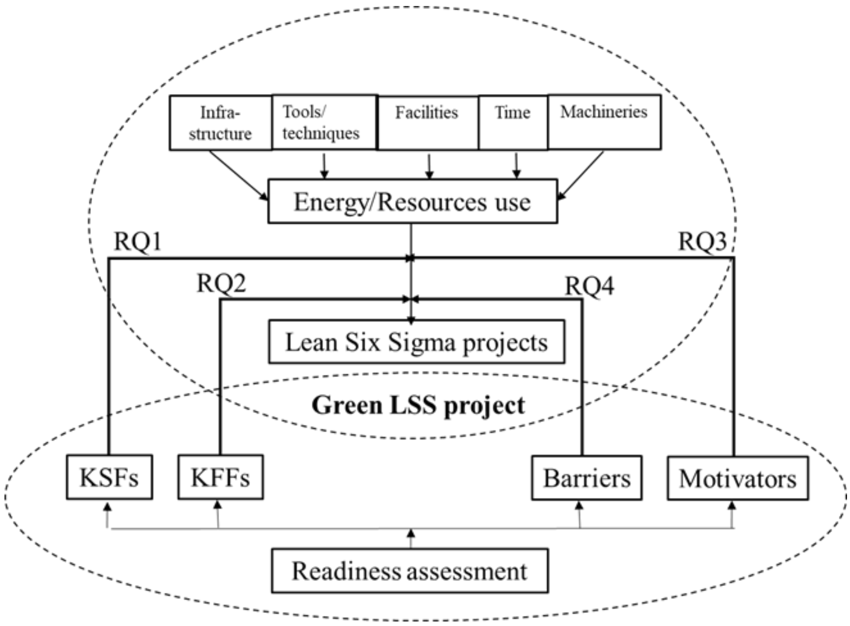


*Figure 1 – Conceptual model for a readiness assessment for green LSS project deployment*

## Research design and data analysis

Having developed the conceptual model through a critical literature review, an exploratory deductive approach was taken with purposive sampling. A survey questionnaire was identified as a suitable instrument to target LSS experts in various sectors of manufacturing and academics around the world to identify top critical readiness factors for the green deployment of LSS projects. It consisted of different sections, including general questions about LSS and green manufacturing experience, and questions concerning each of the four readiness constructs, i.e. CSFs, CFFs, motivators and barriers (Sreedharan et al., 2019). The questions under each construct emerged from the critical literature review, reviewed carefully and validated by the research team with seven-point scaling representing a range of perception from “Not Important” to “Significantly Important”. There was no dependent variable in the study and all variables were treated equally with some assumed linear correlation. Principal Component

Analysis (PCA) was identified as the most suitable analysis technique to understand the data structure and identify fewer dimensions of top readiness factors of green LSS deployment relevant to each construct (Laureani and Antony, 2018). After a careful review of the questionnaire by the research team that included academics and LSS practitioners, the questionnaire was piloted with ten LSS experts before final enhancement and then distributed on-line.

The questionnaire was distributed to 450 experts known through close personal networks, from which 151 usable responses were received (34% response rate) after four months (follow up in the start of third month). PCA was applied as a suitable data reduction analysis technique for this type of scaling analysis using IBM SPSS software. The internal reliability for all four constructs was acceptable with a Cronbach's α for all constructs and their variables > 0.7 (Laureani and Antony, 2018). There was no significant non-response bias or difference (at 95% significance level) between early (first two months) and late (second two months) responses through Leven's homogeneity of variance test. The same test yielded no statistically significant difference (at 95% significance level) among demographic variables such as role, organisational size, sector, experience, LSS skill/qualification, LSS experience and country of respondents. The Kaiser-Meyer-Olkin (KMO) loading for each item within all four constructs was higher than 0.5 with sig < 0.001 of the Barlett's test. This indicated that the sample size was valid with a sufficient correlation between items and at the outset, the PCA fitted well for this data set (Kuvvetli et al., 2016).

The PCA using varimax rotation was performed to look at all variances and form uncorrelated linear combinations of observed variables in each construct (Laureani and Antony, 2018). The varimax rotation method enabled capturing the greatest information based on the least number of factors with the highest loads (Subramanian and Abdulrahman, 2017). Each formed principal component (PC) was ordered in terms of exploratory power or Eigenvalue to explain the proportion of variance created by each component. The components with Eigenvalue >1 were retained as PC that explained the largest portion of the variance in the original data set. Therefore, the components with Eigenvalue <1 were excluded in order to reduce the chance of multicollinearity. Finally, after the varimax rotation, the loading explained how significantly each PC correlated with original variables and how they were influenced by them. However, the interpretation of each PC to label them was a challenging process that needed some brainstorming by the research team. The data set was grouped into four constructs and the variables were analysed individually for each construct.

*Data analysis for four readiness constructs*

As a starting point, the correlation structure indicated that there was some level of modest correlation for all constructs (CSFs, CFFs, motivators, barriers), from which many of them were significant (*sig< 0.001*). This further suggested that there was a sufficient scope for the reduction of data of all of these constructs through PCA. The std. deviation among the variables of all four constructs remained almost constant, with very little variance among them, which indicated no requirement of data standardisation *(CSFs: >0.97 and <1.62); CFFs: >1.27 and <1.69; motivators: >1.2 and <1.68; barriers: >1.1 and <1.64).* The communality (*R2*) of each variable in all four constructs remained high (*CSFs: >0.6 and <0.85; CFFs: (>0.63 and <0.85; motivators: >0.6 and <0.82; barriers: >0.6 and <0.81*). This reflected the proportion of variance of each construct explained by each PC. The total variance explained by Eigenvalue reported that there were 7 retained components for each construct of CSFs (explained 70.5% of the total variance accumulatively), CFFs (explained 72.6% of total variance accumulatively) and barriers (explained 68% of total variance accumulatively) and 5 retained components for motivators (explained 67% of total variance accumulatively) all with Eigenvalue >1. The rotated component matrix was developed through component score ecoefficiency.

## Finding

The descriptive analysis revealed a random balanced approach to different demographic categories in relation to role, sector, organisational size, LSS belt qualification and LSS experience (table 2). The list of established environmental management practices in manufacturers is also presented in this table.

*Table 2 – Descriptive analysis of some ergonomic factors*

| **Role** | | **Size** | |
|---|---|---|---|
| Academic | 8% | Not specified | 27% |
| Consultant | 15% | Large (>250) | 51% |
| CI manager | 29% | Medium (50-249) | 11% |
| Lean practitioner | 2% | Small (10-49) | 7% |
| LSS practitioner | 6% | Micro (<10) | 5% |
| Managing director | 6% | **LSS experience** | |
| Operative | 3% | Not specified | 27% |
| Other | 9% | Never used | 23% |
| Production manager | 5% | < 5 years | 29% |
| Quality manager | 10% | 5-10 years | 11% |
| Supervisor | 7% | 11-20 years | 7% |
| **Sector** | | >20 years | 3% |
| Consultancy | 13% | **Environmental management practice** | |
| Education/Training | 12% | Electricity power use measurement | 17% |
| Manufacturing | 55% | ISO14001 | 23% |
| Not for profit | 1% | None | 5% |
| Others | 2% | Product Life Cycle Assessment | 8% |
| Service | 13% | Product Recycling | 13% |
| Not specified | 3% | Re-Manufacturing | 11% |
| **LSS Belt** | | Re-Using | 7% |
| Not specified | 3% | Waste Management | 1% |
| None | 23% | Waste Reduction | 1% |
| White Belt | 4% | Water Recycling | 14% |
| Yellow Belt | 8% | | |
| Green belt | 13% | | |
| Black Belt | 22% | | |
| Master Black Belt | 29% | | |

Despite dissimilarity in numbers, the analysis of returned responses addressed a cross-geographical study to support a global approach to the research question (figure 2). Nevertheless, no statistical difference was found among respondents from different countries through Leven's Homogeneity of Variance test.

Having run the PCA for all four constructs, rotated components that represent the new set of top readiness factors for each construct were identified. Through a challenging brainstorming process with consensus and cross-checking, each new PC as a new top factor for the green deployment of LSS projects was labelled.

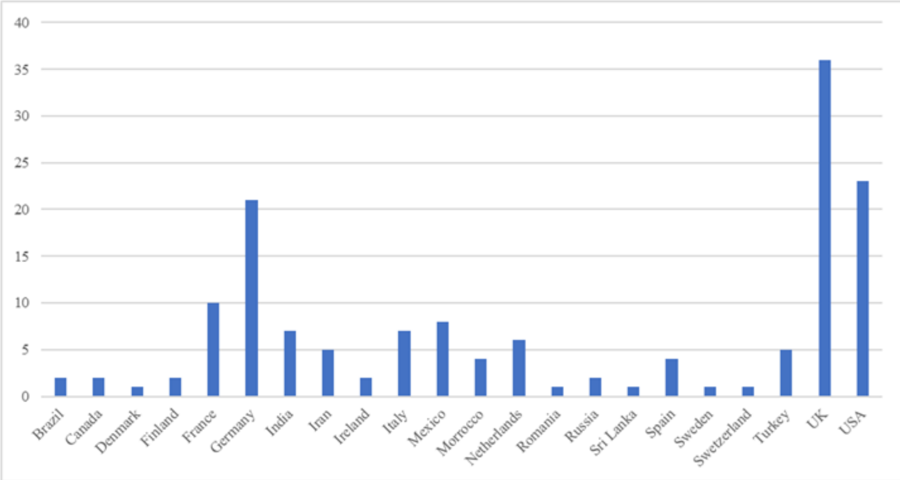


*Figure 2 – Country of respondents*

*RQ1* - The new set of CSFs for the green deployment of LSS projects is depicted in figure 3. It suggests that manufacturers need extensive focus on leadership, commitment in various organisational levels, support from LSS project managers, resources and a collaborative roadmap integrated with environmental sustainability framework to succeed in the deployment of a green LSS project.

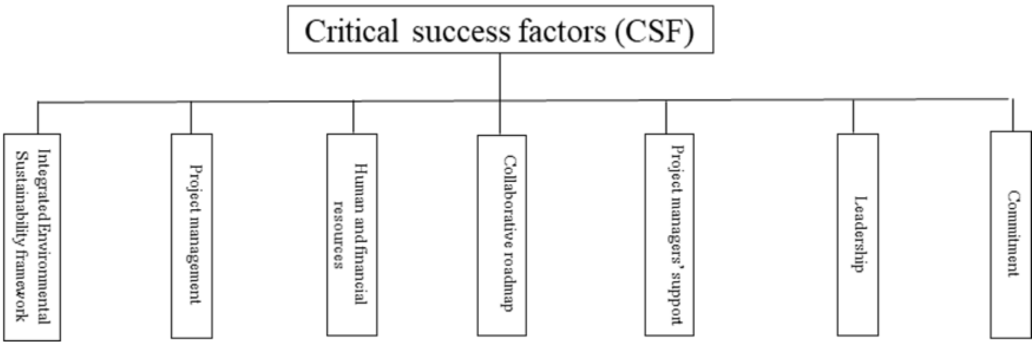


*Figure 3 – New set of top CSFs for the green deployment of LSS projects*

*RQ2* – The Top CFFs that need to be identified and resolved by the manufacturers are presented in figure 4. It was revealed that poor communication and project management, resistance to change, insufficient support and resources, lack of integrated green LSS framework and dynamic training, and complications are listed as top CFFs for any green LSS project deployment.

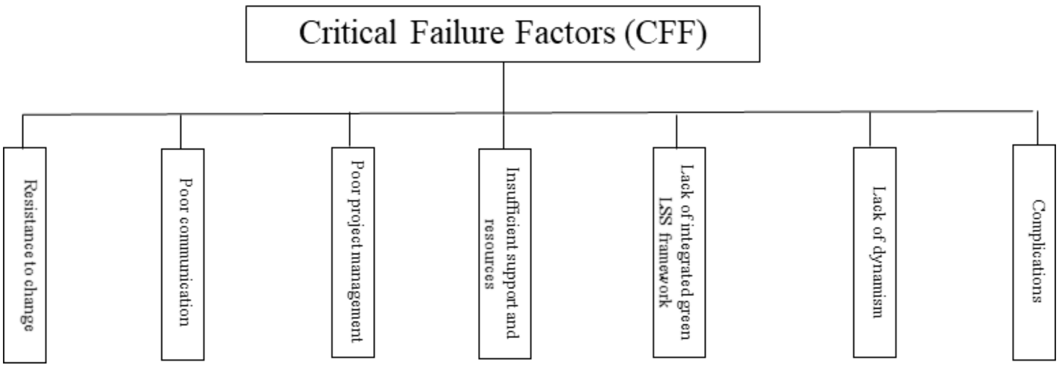


*Figure 4 – New set of top CFFs for the green deployment of LSS projects*

*RQ3* – The new set of motivators to drive manufacturers in the transformation towards green LSS deployment is depicted in figure 5. It was found that energy efficiency objectives such as cost, stakeholders' value, and legal and social demand are key motivators. Furthermore, managerial and environmental initiatives are required to drive managers and employees for any transformation towards the effective deployment of green LSS projects.

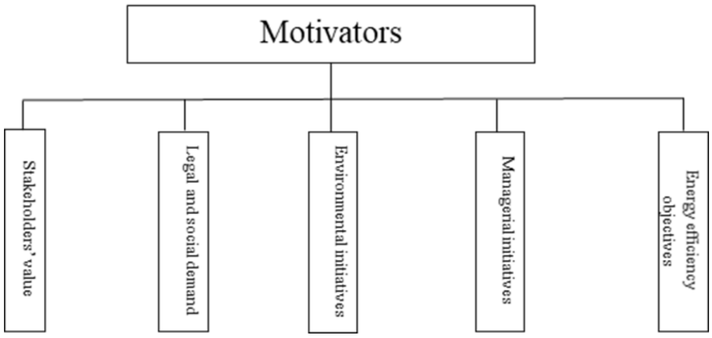


*Figure 5 – New set of top motivators for the green deployment of LSS projects*

*RQ 4* - Finally, the top new barriers that need to be identified and resolved before embarking on transformational change towards green LSS project deployment are depicted in figure 6. It was found that market challenges and LSS obsession and over-burdening are key top barriers. Additionally, social and policy deficiency, strategy and innovation deficiency, cultural and leadership deficiency and deficiency in knowledge, resources and green initiatives were identified as further top barriers.

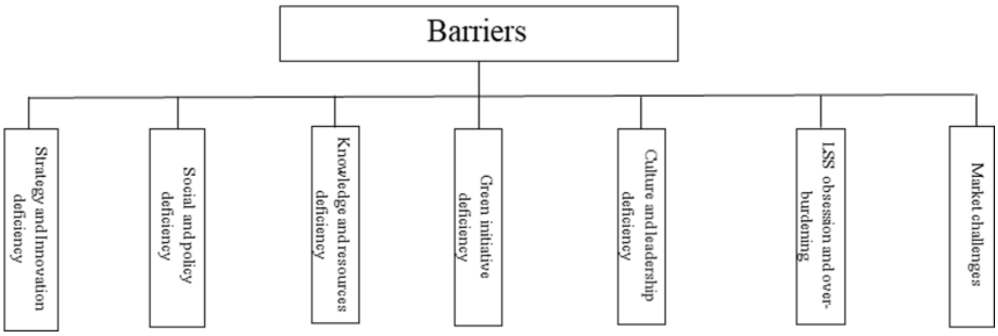


*Figure 6 – New set of top barriers for the green deployment of LSS projects*

**Discussion and theoretical contribution**

Our study contributes to the current GM theories and resource-efficient and stakeholder-oriented practices and systems in manufacturing (Gaikward and Sunnapwar, 2021; Ye et al., 2020; and Aboelmaged, 2018) and green LSS integration (Parmar and Desai, 2020; Farrukh et al., 2020; Cherrafi et al., 2017; Freitas et al., 2017; and Sagnak and Kazancoglu, 2016). The present study fits well as a cross-bridge between these two research disciplines to tackle the research and managerial gap by looking at the transformation to resource-efficient LSS project deployment. Moreover, the study is particularly in line with previous studies that highlighted the challenging and puzzling reality of this transformation and the need for a more holistic view on LSS integration with environmental sustainability such as readiness assessment to broaden the maximisation of benefits (Aboelmaged, 2018; Ruben et al., 2018; and De Freitas et al., 2017).

It was identified there are some common CSFs and CFFs for the green deployment of LSS projects as for LSS and green LSS with a green outcome, whilst there are some crucial CSFs for the green LSS deployment. This study has a direct contribution to the existing literature (Farrukh et al., 2020; Shokri et al, 2021; and Kaswan, 2019) by demonstrating the importance of assessing motivators and barriers for any transformational movement of LSS, including the green deployment of LSS projects.

Our study is a preliminary study in the discipline. It empirically validates and assesses the framework of a new reduced set of readiness factors for the green deployment of LSS projects. We have developed an effective and efficient list of CSFs, CFFs, barriers to and motivators of transformation to and the implementation of green LSS project deployment. The present study has a strong contribution to existing literature (Sreedharan et al., 2018) that highlighted the importance of a systematic integrated readiness assessment framework for any green LSS integration, including green LSS deployment of LSS projects.

**Conclusion, managerial implications and future studies**

The aim of the study was to recommend a systematic and effective readiness self-assessment framework for the green and energy-efficient deployment of LSS projects in manufacturing organisations. Through this empirical global study, it is concluded that there are series of a new set of readiness factors to be addressed as barriers to and drivers of transformation and CSFs and CFFs for the implementation of green LSS projects. This systematic framework of readiness self-assessment will provide precious insight for managers and LSS practitioners and champions to assist them to effectively and efficiently evaluate their organisational capability for transforming to an energy-efficient and outcome-oriented LSS project deployment. In fact, our study enlightens the vision of manufacturing managers and LSS practitioners to transform to more sustainable stakeholder-oriented LSS project deployment rather than output-oriented projects. Scholars can exploit insight from this study to reinforce their knowledge base on the readiness assessment of a new perspective of green LSS integration.

Despite the high degree of generalisability, validity and credibility of this global empirical study through quantitative analysis, it is considered that there is a need for more in-depth and critical analysis of the readiness framework in practice. This includes a further investigation of the feasibility of green LSS project deployment and vision of managers and LSS practitioners through an interpretive and realistic strand of research such as interview and case study. Other future research opportunity is to conducting a qualitative analysis to capture the understanding and willingness of LSS practitioners and CI consultants towards this paradigm shift in more depth and also understanding the inter-relationship between readiness factors in each construct.

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